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ABSTRACT

The findings and 13 recommendations of a NSF Advisory Council task force that evaluated universities as centers of basic research are presented. Listed are the major strengths of universities as centers for basic research (including continuity and tradition, freedom of research, interactions among disciplines) and such threats to their viability as declining enrollments, aging of faculties, lack of faculty positions for young scientists, inadequate funding, deterioration and obsolescence of physical plants and scientific instruments, increasing regulations, pressures for applied research, and conflict between research and teaching. The 13 recommendations proposed deal with the following areas: post doctoral fellowships; research career development awards; research scientist awards; national research professorships; undergraduate summer research participation; assistance to teaching institutions; research on research; retirement plans and incentives for early retirement; equipment needs and utilization; facilities; impact of federal regulations; and uncoupling research and teaching. (BD)

CONTINUED VIABILITY OF UNIVERSITIES AS CENTERS FOR BASIC RESEARCH

REPORT OF TASK GROUP #1

NATIONAL SCIENCE FOUNDATION ADVISORY COUNCIL

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RECOMMENDATIONS

1. NSF establish a national postdoctoral fellowship program with three-year awards to candidates who at the time of their applications have not had their Ph.D. degree for more than one year.

2. NSF institute Research Career Development Awards to universities on behalf of specified young scientists who have already demonstrated their research potential but are not yet established as independent investigators.

3. NSF establish Research Scientist Awards to individuals who in their mid-career are already on university faculties and merit support for three years to change scientific fields or intensify their research activity.

4. NSF establish National Research Professorships based on university nominations of internationally distinguished scientists whose contributions to basic research would be enhanced through full-time scientific activity.

5. NSF devise a program of Undergraduate Research Opportunity Awards permitting outstanding students to participate in summer research.

6. NSF consider special programs designed to enhance teaching and research at those undergraduate institutions with demonstrated records of effective education in science.

7. NSF through a Task Group and in-house staff conduct more and better research on the process of scientific research.

8. NSF continue studies of alternative arrangements for encouraging cooperative basic research between universities and industrial laboratories.

9. NSF in collaboration with universities and professional societies continue investigation of existing retirement plans, retirement practices, incentive plans to encourage early retirement, and the potential impact of recent legislation on the aging of faculties.

10. NSF in conjunction with universities and professional societies continue investigations of equipment needs, maintenance and utilization for scientific research in different fields.

11. NSF in conjunction with universities conduct a study of existing laboratory facilities and their usage in order to prepare a realistic appraisal of needs for new laboratory construction.

12. NSF convene a Task Group to consider ways to ameliorate the deleterious impact of federal regulations on the conduct and cost of basic scientific research.

13. NSF convene a Task Group to study existing policies within universities regarding allocation of teaching and research effort and salaries and consider alternative ways to uncouple research and teaching so that any decline in the number of teachers required in universities will not automatically lead to a reduction in scientific research.

INTRODUCTION

Any prospective evaluation of universities as centers of basic research must confront a series of threats to these institutions including: decreasing enrollments, aging faculty, elimination of mandatory retirement policies, declining faculty positions for young scientists, inadequate and unstable financial support, increases in the fraction of funding for specified, categorical purposes, deterioration of laboratories and libraries, obsolescence of scientific instruments, extension of inflexible controls limiting the freedom of investigators, additional burdens of accountability, and decreasing public confidence in science and technology. Foreboding as the prospects seem, we should recall that universities have repeatedly demonstrated their resiliency in coping with great challenges like the depression in the 1930's, World War II, the post-war growth of the student body, and the explosive expansion of the 1950's and 1960's. Concerned as we are about the plight and problems of universities, we did not in preparing this report attempt to design an aid program for them. Instead we focused on a set of proposals aimed at maintaining a vigorous national program of basic scientific research in which the universities occupy a central place.

In approaching our task we recognize that some of our remedies are designed for the short term and others for a longer period. Some of the recommendations are particularly applicable to certain institutions and disciplines and less relevant to others. We interpret "universities" in a broad sense to include four-year colleges as well as research universities since we are concerned with the discovery and inspiration of talented young people who in later years will become leading research scientists. Hence one of our recommendations is specifically directed toward small colleges which have distinguished records in graduating students who subsequently achieved doctorates elsewhere (1). Other recommendations deal with postdoctoral fellowships for young investigators just starting their scientific careers, career development awards aimed at creating faculty positions at the assistant professorship level, mid-career fellowships to permit young faculty members to change fields, and national professorships to outstanding scientists so that their research activities can be intensified.

Throughout our deliberations we were guided by the assigned task

> "Consider the problems or potential problems of the coming decade which may threaten the viability of universities as centers for basic research. What present NSF programs are likely to have an impact on these problems? What new programs or changes in existing NSF programs might be desirable to assist universities in overcoming these problems?"

In our attempts to cope with this assignment we were aware that the fundamental premise that "universities are centers of basic research" has been questioned. For example, Arthur D. Little (2) in his 1913 presidential address before the American Chemical Society wrote

> "A constantly rising proportion of our best research is carried on in the laboratories of our great industrial corporations."

This view is to be contrasted with that of another industrial researcher, J. J. Carty of the American Telephone and Telegraph Company who argued (3)

> "The natural home of pure science and of pure scientific research is to be found in the university from which it cannot pass"

and that financial support for that research was to come from

> "those generous and public-spirited men and women who desire to dispose of their wealth in a manner well calculated to advance the welfare of mankind and it (funds for research) should come from the industries themselves, which owe such a heavy debt to science."

These different perceptions continue to the present time and the issue is still not resolved. In our view basic research is conducted in diverse environments and one section of our report deals with this matter. We are aware, however, that evaluations of research are frequently subjective and anecdotal; as a result there are different opinions as to the origin of important scientific discoveries, the value of targeted vs. non-targeted research, and the cause of the delays between the actual discoveries and their application (4,5,6). In order to obtain a more objective view of what may be called the sociology of scientific research we recommend that a Task Group be established to conduct research on the research process.

As we considered one or another of the threats enumerated above, tentative recommendations were formulated which seemed to offer potential solutions.

Invariably defects were detected on further reflection and we were tempted to discard the proposals. In most cases we recognize the need for further study. For example, any plans developed last year regarding inducements for early retirement of faculty members must be considered anew because of the curtailment of mandatory retirement policies. Recent reports have questioned whether specific plans to aid scientific research through inducements of early retirement of aging faculty members are likely to be meaningful (7). We consider this issue to be enormously complicated and worthy of an independent detailed analysis. To some extent this is a problem primarily for the universities but clearly the National Science Foundation can aid in the analysis. Accordingly we recommend further studies of voluntary retirement practices, career shifts, and mobility of scientists in various fields. Even in those problem areas where we make specific recommendations such as the establishment of career development faculty awards we recognize disadvantages. These need to be evaluated further so that a determination can be made whether the gains in pursuing a specific direction outweigh the potential losses.

This has been an especially difficult report to write for a number of reasons. First, the task was very broad and the problems enormously complex. For an assignment of this magnitude we should have been meeting much more often and had extensive staff resources so that summaries of relevant literature and position papers could be prepared. Second, all members of the Task Group had commitments and obligations which precluded their participation in the task to the extent needed and desired. Third, within the Task Group perceptions of problems and what might be considered appropriate or legitimate remedies were so different that much of our effort was expended in general discussions which, though enlightening, did not lead to a written document. Some of us view the situation from the vantage point of the small prestigious colleges which will be affected only slightly by some of the critical problems like decreasing enrollments. In terms of remedies what some of us consider necessary and justified, such as targeted funds or removal of constraints, are viewed by others as unwarranted, special treatment. A postdoctoral fellowship program funded through national awards seems very attractive to those in a particular scientific discipline whereas others feel that this type of program may not identify and reward the most talented young scholars in their field of science.

One dilemma arose continually during our deliberations just as it confronted those who advocated federal support for science during the debates leading to the establishment of the National Science Foundation. Many of our proposals doubtless would lead to the granting of funds to researchers and institutions of proven excellence. As a result the strong would become even stronger. We are aware of the political realities and the pressures for distribution of funds according to traditional geographical patterns. Hence to avoid too great a concentration of financial support to a few institutions we devoted much effort to consideration of proposals to aid institutions outside of the northeastern, central and western plains. Finally, it has not been easy to develop ideas which have not already been proposed and discussed in the many recent excellent studies on the State of Academic Science (8,9,10). In view of these difficulties, this report and especially the recommendations must be considered as a tentative framework which we hope will provide a useful basis for further study by other task groups.

UNIVERSITIES AS CENTERS FOR BASIC RESEARCH

In 1945 Vannevar Bush (11) reporting to President Roosevelt wrote:

> "Publicly and privately supported colleges and universities and the endowed research institutes must furnish both the new scientific knowledge and the trained research workers. These institutions are uniquely qualified by tradition and by their special characteristics to carry on basic research. They are charged with the responsibility of conserving the knowledge accumulated by the past, imparting that knowledge to students, and contributing new knowledge of all kinds. It is chiefly in these institutions that scientists may work in an atmosphere which is relatively free from the adverse pressure of convention, prejudice, or commercial necessity. At their best they provide the scientific worker with a strong sense of solidarity and security, as well as a substantial degree of personal intellectual freedom. All of these factors are of great importance in the development of new knowledge, since much of new knowledge is certain to arouse opposition because of its tendency to challenge current beliefs or practice.
>
> "Industry is generally inhibited by preconceived goals, by its own clearly defined standards, and by the constant pressure of commercial necessity. Satisfactory progress in basic science seldom occurs under conditions prevailing in the normal industrial laboratory. There are some notable exceptions, it is true, but even in such cases it is rarely possible to match the universities in respect to the freedom which is so important to scientific discovery."

Although this point of view is questioned by some and the nature and scope of scientific inquiry have changed dramatically in the ensuing 30 years, we accept the premise in the assignment to the Task Group that universities function as centers for basic research. In adopting that position we define basic research (12) as

> "that type of research which is directed toward increase of knowledge in science. It is research where the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than a practical application thereof."

and recognize that such research is now being performed in a variety of settings. These include in addition to graduate universities, colleges, professional schools, industrial laboratories, federally funded research development centers (FFRDC's), government in-house laboratories, and profit-making as well as not-for-profit private research institutes. Indeed this division seems appropriate in view of the great diversity of institutions and the differences among scientific disciplines.

Universities differ among themselves in many ways. Thus any discussion of basic scientific research at universities must be carried out with a sense of how widely universities differ in their abilities and commitments to carry out basic research (and the advanced training of students that goes along with that basic research).

At one ~~end~~ of the scale there is a handful of the very best research universities. All, or nearly all, of their science departments are first-class, and some (changing over time) at each of these superior universities are unsurpassed. The faculties of such superbly good departments are in a continuing state of fierce competition and simultaneous fraternal cooperation. Competition resides in the search for important new scientific data, theories and insights -- and hence also in attempts to recruit and retain the very best investigators. Cooperation arises from the same search for truth and understanding; the cross-cutting tensions of loyalty to one's university and to one's discipline might create neurotic chaos, but for most faculty members they create just the opposite: a healthy, bustling, busy, intense life of devotion, constant criticism of self and others, and glory in important new scientific achievements as they come along.

At the other end of the scale there are some universities and many colleges in which serious research is rare or absent. Teaching is the main professional occupation at such institutions, and primarily undergraduate teaching. Graduate teaching, to be at all passable, requires close contact with active faculty research. We do not wish to denigrate such non-research-oriented institutions. On the contrary, these institutions are largely responsible for finding, recognizing, inspiring and teaching young people who then go on to productive scholarly careers in science. Given the heterogeneity of our society and its history, it is plain how these "teaching" institutions have arisen. They will, of course, include some faculty members who have real ability and interest in basic research (especially in non-laboratory fields) but who stay where they are for a variety of personal reasons. In the main, however, these institutions contribute to basic research primarily by discovering those relatively few unusually gifted students capable of becoming effective research scientists and encouraging them to move as soon as possible to universities appropriate to their abilities. That discovery of great ability in a youngster who may never have dreamed of scientific research as he or she struggled through inferior early education is an oft-told tale, and yet a tale still not tellable often enough.

Between these two extremes of the basic research spectrum there are universities of many kinds. For example, one may find a good, but not superior, university with two or three world-class departments. Engineering or technological schools form a somewhat separate group. This great dispersion, so easily neglected in public discussions of universities (or universities plus colleges), makes for confusion. It affects the debate about geographical spread of federal research funds; it affects discussions of science education; it is ever-present in the background when allocation of funds is in question.

The major strengths of universities as centers for basic research are:

1. Continuity and tradition. Fiscally, psychologically, and morally, good universities have great momentum. Paradoxically, individual departments can have great fragility, but, generally speaking, departments that are superior tend to remain so for long periods, and not-so-good departments find it very difficult to improve themselves. Great scholars attract the brightest minds for training, and great departments are able to recruit the best young

scholars at entry levels. The fiscal momentum of great universities is still considerable, but notably less than before the introduction of massive federal funding of research. Modern research in most fields of science requires expensive equipment and staff.

2. Freedom of research. At a good university, the senior research-oriented scientist turns his or her attention to those research problems that seem most important. Subject to the need for equipment and staff funding, the search for truth can go on largely untouched by the passions of politics, convention or prejudice or even by transient disciplinary fads. That is perhaps too idealized a picture, but at the best universities it is a fair approximation. Society has had rich returns from that kind of freedom, which finds its best homes at universities where current beliefs and practices are often challenged. Some industrial and government laboratories provide approximations to university conditions, but hardly ever with the same degree of insulation and continuity.

It is worth quoting here Bush's analog of Gresham's law (11,12):

> ".... it is important to emphasize that there is a perverse law governing research: Under the pressure for immediate results, and unless deliberate policies are set up to guard against this, applied research invariably drives out pure (basic).
>
> "The moral is clear: It is pure (basic) research which deserves and requires special protection and specially assured support."

3. Interactions among different disciplines. At the best universities, discussions among scholars in different fields often yield unexpected and abundant harvests. That is not surprising for relatively nearby fields, physics and chemistry, for example, or mathematics and statistics. Yet investigations in widely separated fields can find creative stimulation from each other: music and physics, mathematics and philosophy, anthropology and geology. At a good university, this kind of interaction can begin in formal settings -- a doctoral defense, a department seminar -- or in informal ways -- a luncheon conversation, a chance meeting across the back fence. Service on university committees, e.g., publications or appointment committees, often brings together unlikely colleagues.

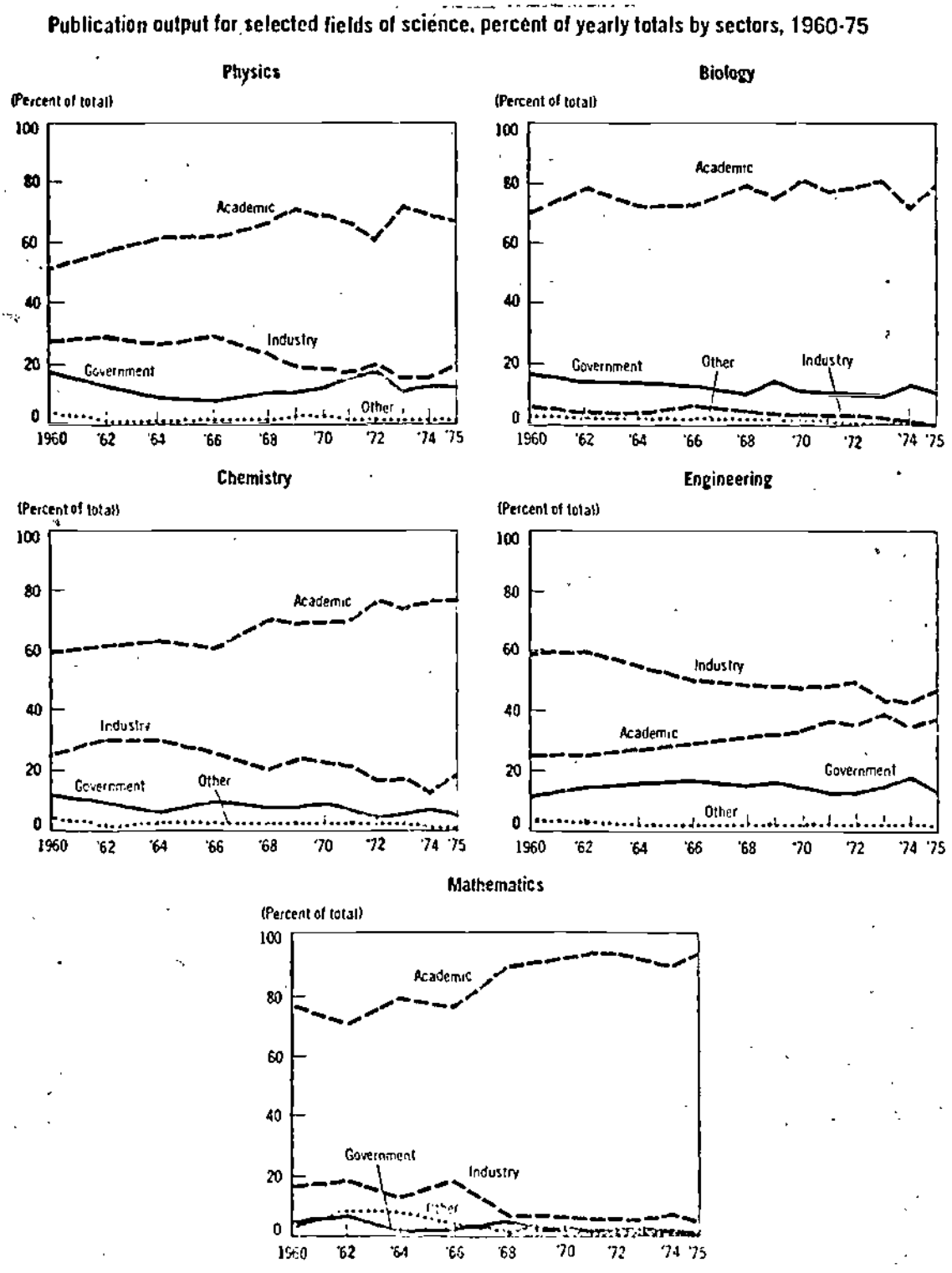
4. Students. The presence of extremely bright, active, questioning, ambitious graduate students gives universities part of their special character. The entering student just may see something that the senior professor neglected. The advanced student and the professor are more nearly colleagues. Good students are not only our intellectual descendents-to-be, our hostages to the future, sometimes our children in senses almost as intense as that of biological children. They also keep us honest, prevent cant, and the best persistently raise tough questions .... and the best persistently raise tough questions .... and try to answer them with us.

5. Dual responsibilities of universities. Traditionally universities are responsible not only for contributing new knowledge of all kinds but also for maintaining the knowledge of the past and imparting it to students. As a consequence, scientists in universities are surrounded with colleagues who have an appreciation and understanding of the value of new knowledge.

Scientists who work in academic settings currently perform a significant share of our basic research. They accounted for 55% of such work in 1976, spending an estimated total of $2.6 billion. This is in sharp contrast to 1953 when universities and colleges accounted for only 26% of basic research expenditures. The important role universities and colleges play in the performance of basic research is also reflected by the very large fraction of articles which academic scientists and engineers contributed to the literature. This dominance for the fields of physics, biology, mathematics and chemistry is shown in Figure 1 along with the corresponding data for engineering where industrial research is a much more significant fraction of the total (13).

Although academic science has maintained impressive levels of productivity in recent decades there is concern over a possible decline in the scope, quality, and pace of basic research conducted in universities. The constraints giving rise to this concern include diminished and inconstant funding, declining opportunities for young researchers and thus an aging faculty, increasing costs and restrictions associated with new federal regulations and declining enrollments. It is relevant therefore to ask, "Can the country continue to rely on university-based scientists to perform a significant fraction of our basic research?"

Figure 1


Publication output for selected fields of science, percent of yearly totals by sectors, 1960-75
Physics
(Percent of total)
Academic
Industry
Government
Other
Biology
(Percent of total)
Academic
Government
Other
Industry
Chemistry
(Percent of total)
Academic
Industry
Government
Other
Engineering
(Percent of total)
Industry
Academic
Government
Other
Mathematics
(Percent of total)
Academic
Government
Industry
Other
100
80
60
40
20
0
1960
'62
'64
'66
'68
'70
'72
'74
'75

The real decline of federal funds to support facilities, equipment, and research projects poses particular problems for universities whose expanded science departments are in effect research institutes within university structures. At the same time, concern for increasing participation in research funding by institutions and a stream of young investigators who have not already benefited from substantial research support motivates distributing already scarce resources more broadly. We assume that universities will respond to their individual difficulties as best they can, and that they will strive to maintain high standards in teaching and research. But their high level of productivity in basic research will decline as the federal support which engendered and sustains it declines.

In principle, the welfare of academic science may be distinguishable from the health of scientific research. We now have a diversity of environments which foster high-quality basic scientific research. But despite this diversity of institutions, the health of basic research is not in practice distinct from the welfare of academic science. One reason for this is that our basic research in many areas occurs predominantly in academic settings. In these areas, the financial constraints on universities which entail minimal employment and basic research opportunities for young investigators during the coming decade will directly affect scientific productivity: much of a decade of trained or potential talent could be lost to basic research in these areas. Another reason for particular concern for the welfare of academic science is that universities occupy a predominant role in identifying, recruiting, training, and evaluating new scientists. Since the skill with which academic scientists perform these functions affects the health of research in all its settings, impediments to the vitality of academic science have multiple effects.

Still, one might question whether universities' status as centers for basic research ought to be preserved, since it can be argued that some sorts of research progress more efficiently in research institutes which are independent of university structures. We believe that the desirability of such research institutes varies considerably by field, but that the feasibility of founding new institutes in some areas deserves exploration. But for areas where the majority of basic research now takes place in university settings,

we feel that the burden of proof in the argument for the establishment of new research institutes must be borne by the advocates of such a substantial shift in the allocation of scarce resources.

In our view the linkage between research and teaching, the challenge of the young, the freedom to explore, the responsibility for finding, inspiring and training future scientists, the continuous flow of fresh talent, the institutional long-term stability and history, the receptivity to mavericks, the recently developed relationship to other centers such as FFRDC's, industrial laboratories, private for-profit and non-profit research institutions, and the absence of specific expectations for "useful results" continue to make universities the ideal centers for basic research.

THREATS TO VIABILITY OF UNIVERSITIES AS CENTERS FOR BASIC RESEARCH

Much has been written in the past four years about the problems facing research universities and the need for changes if they are to continue as centers for basic research (8,9,10). Hence in this section we will merely list some of the principal problems without attempting to present extensive documentation. It should be emphasized that a critical problem for one type of institution is of little significance to another and what is a very serious threat in one field may have no impact in another. Thus the diversity of universities -- large and small, public and private, rich and poor, graduate and undergraduate -- and of disciplines -- physics and biology, mathematics and engineering, chemistry and social sciences -- must be considered in evaluating the severity of any apparent threat to institutions and scientists on whom we depend for basic research. Some of the apparent threats are likely to be short-term. Clearly the proposed remedies for these must be different from the recommendations to solve the long-term problems.

1. Declining enrollments. Demographic studies of higher education (14) indicate that enrollment at colleges tracks births with a delay of about 20 years. Although projections of enrollments in institutions of higher education are not nearly as accurate as projections for elementary and secondary schools, it is widely recognized that the decline in the number of births from 4.3 million in 1961 to about 3 million in the mid-1970's will have a profound effect on college enrollments in the late 1980's and 1990's. The consequences

of this anticipated decrease in university enrollment on the size of faculties in institutions of higher learning seem obvious.

2. Aging of faculties. During the past two decades there has been a tremendous growth in the number and size of universities and a concomitant expansion in the number of faculty members, many of whom will not retire during the next 10 years. The almost explosive growth coupled with new national and local legislation altering retirement practices is leading to a marked aging of faculty members.

3. Lack of faculty positions for young scientists. In view of the apparent decreasing need for teachers and the occupancy of tenured slots by faculty who will not retire for some time, recent Ph.D.'s are already having great difficulties finding faculty positions. The NSF Advisory Committee for Physics described this situation recently as a "major emergency". Because of the tight coupling of teaching and research functions in many universities there is a real danger that a generation of extremely able scholars will be lost in terms of their potential contributions to science.

4. Inadequate and unstable funding. In "Science, the Endless Frontier", Vannevar Bush (11) listed five fundamental principles which must underlie a program of government support for scientific research and education if such support is to be effective. The first of these is:

> "Whatever the extent of support may be, there must be stability of funds over a period of years so that long-range programs may be undertaken."

Since basic research is a long-term process, wide fluctuations in support are deleterious, and the continuity and stability of basic research are thereby threatened.

5. Limitations in number of fellowships. In the discussion on the renewal of our scientific talent President Conant wrote:

> "..... in every section of the entire area where the word science may properly be applied, the limiting factor is a human one. We shall have rapid or slow advance in this direction or that depending on the number of really first-class men who are engaged in the work in question..... So in the last analysis the future of science in this country will be determined by our basic educational policy."

Educational patterns for young scientists almost invariably involve their spending a few years following their obtaining Ph.D. degrees in postdoctoral research and training. Yet in many fields of science there are few fellowship opportunities with the result that these individuals are supported through grants to senior scientists. A national postdoctoral fellowship program would represent an alternative path which may be more effective in finding the most talented young scientists and in fostering original research.

6. Deterioration of physical plants. During the 1950's and 1960's research universities experienced enormous growth in their physical plants as new teaching and research laboratories were constructed to accommodate the enlarged student bodies. Funds for such construction today are virtually non-existent and it is clear that research facilities in most fields are no longer adequate for the conduct of modern scientific research.

7. Obsolescence of scientific instruments. Whereas in the 1960's grants from NSF and other federal agencies routinely included significant funds for the purchase of sophisticated scientific instruments, now it is extremely difficult to secure such funds. Yet it is apparent to all who do experimental work that the tools purchased 15 years ago are frequently no longer suited for innovative, quantitative research. Although programs have been initiated to alleviate this problem by funding groups of investigators who will share the use of expensive equipment, the total funds available are grossly inadequate to satisfy the critical needs for new instruments.

8. Curtailment of libraries. The growth of universities and scientific research during the 1960's has been accompanied by an explosive growth of the scientific literature in the form of books and scholarly journals. Publication costs have also risen greatly. But growth of library budgets and facilities has not occurred. As a consequence research scientists have been impeded in their work because of the inability of libraries to maintain the services, monographs, and journals needed for the conduct of research.

9. Increasing regulations and interference with creative activity. In the discussion above on the need for stability of funding patterns we quoted Vannevar Bush (11) regarding essential fundamental principles for the support

of scientific research through government grants and contracts. Another fundamental is particularly relevant here:

> "Support of basic research in the public and private colleges, universities, and research institutes must leave the internal control of policy, personnel, and the method and scope of the research to the institutions themselves. This is of the utmost importance."

It is obvious that we have come a long way since Bush listed this principle. Research on human subjects, DNA recombinant technology, OSHA, utilization of equipment, multiple report writing, accounting for percentage of time spent on research, affirmative action programs, radiation safety, space utilization, and personnel administration are subjects which now confront most researchers (15). Compliance with federal and state regulations on these and other subjects occupy the scientists' time and energy and consume significant fractions of their research budgets. There seems little doubt but that considerable creative activity is lost by researchers in coping with these regulations and the requirements for accountability. Yet the goals these regulatory measures are designed to achieve are generally worthwhile and justifiable, and compliance is necessary. How we can reconcile the needs for freedom in research and legitimate constraints and requirements for accountability is currently a major problem. As indicated by Smith and Karlesky (8):

> "Few subjects so deeply trouble educators as the sharply deteriorating relationship between government, both state and federal, and the universities."

10. Pressures for targeted and applied research. In the invitation to participants in a Symposium on Basic Research in 1959 sponsored by the National Academy of Sciences, the American Association for the Advancement of Science, and the Alfred P. Sloan Foundation, Warren Weaver (16) posed the following questions which are relevant today, almost 20 years later:

> "1. Is not the large support of applied research, and still more particularly the massive present support of development, in unhealthy relation to the meager support for basic research?
>
> 2. Is it not true that industry pays eager lip service to basic research, but in actual fact does not give adequate support to basic research, either within industry or elsewhere?
>
> 3. Has either industry or government learned how to protect basic research from the insistent demands of applied research and development?

4. Are not universities so deeply invaded by the demands for solving immediate problems and by the temptation of income for so doing, that there are all too few cases of competent scholars pondering about problems simply because it interests them to do so? Is there not a real danger that the scholars in our universities will lose--and indeed have already partly lost--the 'maneuvering room for their continuing reanalysis of the universe?'

5. Has it been effectively accepted in our country that the spirit of basic research is an essential ingredient of the educational process--and that this fact should affect educational procedures at all levels?"

Increasingly in recent years scientists in justifying their requests for increased funding for research and development have been arguing that such increases will lead automatically to economic benefits and growth. As was made clear at the colloquium on Research and Development in the Federal Budget sponsored by AAAS in June, 1978 the chain of events is really more complex. At that meeting (17) Russell Peterson, Director of the Office of Technology Assessment, pointed out the dangers in drawing a connection between research and economic growth with the following remarks:

> "The move by the President in his 1979 budget to include more funds for basic research is encouraging, but the words used tying such research to economic benefits are disturbing. Unless we continue to support substantial basic research with no other objective in mind than the uninhibited search for knowledge, we will erode the very foundations of technological progress."

It is our impression, although we have no documentation, that as funds for research diminish pressures for targeted or applied research increase. Is it now easier to obtain funds from NIH, for example, to do research which some branch of that agency wants done (because of some societal concern) than it is to secure a grant on a subject initiated by the investigator? Are research scientists adapting to that perceived situation by changing their research activities so as to obtain these funds? Is he who pays the piper playing the tune?

11. Conflict between research and teaching. There is general agreement that participation in both research and graduate teaching is beneficial to the practicing scientists and the students aspiring to careers in science. However, research universities have experienced tensions because of the conflicting

obligations and commitments of the faculty to creative research and undergraduate instruction. Indeed the obvious variations in faculty "teaching loads" among different universities, campuses in the same university, and colleges have caused considerable conflict. On the one hand, the "teachers" in the outstanding small colleges are striving for freedom to do research and, on the other hand, the research-oriented faculty members are being pressured to accept increased responsibilities for undergraduate instruction. Within public universities accounting for faculty members' time has become a frequent demand because legislators view the faculties as not devoting sufficient time to teaching. These conflicts have been exacerbated by the federal funding of the research of individual university scientists who with their students and postdoctoral associates create de facto research institutes where research is even more heavily emphasized. Debates about the establishment of Research Professorships continue but as yet the problems are not resolved. Faculty members continue to be recruited to universities based largely on teaching needs even though those same institutions publicly applaud and reward those individuals more for their research accomplishments than for their successful teaching.

12. Worsening of public image of science. Criticism of science by the public, government officials, and special interest groups is not new. It does seem, however, that the decrease in public esteem of science has intensified in recent years. Much of this worsening image of science can be attributed to rapid social and economic changes. In addition scientific research has become sufficiently large in scope and budgeted funds that average citizens are more likely to feel affected personally by science policy and identify science as a target for their frustrations and irritations. Questions are being raised as to how the money is spent and why the returns for social gain have not been greater. When one considers that, despite the rhetoric about the value of new knowledge for its own sake, the primary reason for federal support of basic research is a practical one, i.e., to strengthen national defense, to improve health, to stimulate the economy, and to enhance national prestige, it is not surprising that the public and government are expecting and demanding rapid returns for the research dollars. As expressed by Wolfle (18) universities will have to:

> "cope with demands for accountability, with skepticism over their motives and their management, and with further attempts to control their activities and define their objectives."

Have scientists been effective in the arena of public policy? Have they promised too much and too soon in the cure of cancer and in solving our energy problems? Have they accepted the challenges and attempted to supply answers to the list of public criticisms listed by Hutt (19)?

(a) Health science research is not presently designed to help the public which pays for it.

(b) The public should have greater control over, and protection from health science research.

(c) Federal funding of training for health science research is an inappropriate use of tax funds.

For scientific inquiry to gain the support many of us consider essential, we will have to be more vigorous and convincing in defense of current policies and changes in them that seem necessary.

RECOMMENDATIONS

During the discussions of the problems outlined in the previous section much of our effort was devoted to the formulation of potential solutions. Throughout these deliberations we were confronted repeatedly with the reality that we simply did not know enough about the complexity of some of the issues to propose remedies. In trying to cope with the problem of aging faculties, for example, we concluded that much more information was needed. Accordingly we called for additional study. In other instances we felt that a specific proposal was warranted even though some of us detected weaknesses in the recommendation. Even for those problems where a remedy is proposed we did not have sufficient time to present specific details of the type that are doubtless necessary. Nor was there an occasion where all Task Group members were present to assess the strengths and weaknesses of the proposal. Hence these recommendations are presented here to stimulate further consideration either by other task groups or by the staff of the NSF. We hope that they will provide a structure for further study in terms of priorities and resources. Having a Task Group composed of individuals of such diverse backgrounds and interests -- industry, law, administration, psychology, statistics, philosophy, social and biological sciences, large and small universities -- was in many ways a considerable advantage. But in the formulation of specific proposals we found

that a proposal based on one member's familiarity with a scientific discipline may not be appropriate for another field. This experience within our group may be of use to the Advisory Council in establishing for the next phase of the analysis more homogeneous study groups.

1. Postdoctoral fellowships. Finding and encouraging young people who exhibit extraordinary scientific talent represent one of our highest priorities. Hence we support enthusiastically the recent action of the National Science Board to establish a Young Investigators' Postdoctoral Program. In our view the award of postdoctoral fellowships through a national competition where the fellows select the institutions and the investigator with whom they would like to work is preferable to the hiring of postdoctoral fellows by more senior investigators who receive grants from NSF with stipends in their budgets. Hence the funds for the program would come from the existing grants. We recognize that many of the awardees will select the prestigious institutions for the tenure of their fellowship. But we doubt whether this concentration of talent would be any greater than in the present system. The principal issue is whether the national competition is more likely to select the most talented young investigators than the system where the grantee with funds recruits fellows by existing methods. Evidence is lacking on this subject but experience with the postdoctoral program of NIH indicates that the national award program is more selective. Although many of those selected for these postdoctoral fellowships will doubtless come from the outstanding universities we think it likely that a substantial number will also come from institutions not in the forefront of basic research. The national award program is more consistent with the democratic ideal of equal opportunity than the present system where postdoctoral positions are filled largely through private negotiations based on "connections".

In considering this proposal we aim to support for three years those outstanding individuals who just obtained their Ph.D. degree. In this report our recommendation differs from that of the National Science Board which supports "persons less than five years from the Ph.D." Unless there is a significant change in faculty recruitment practices, individuals with four years of postdoctoral experience followed by three years of an NSF national postdoctoral fellowship will have difficulty in securing a position as an assistant professor.

Such individuals would be too old and experienced for assistant professorships and not sufficiently tested and independent for associate professorships. Thus we propose that this program be designed for individuals who have just received their Ph.D. degrees.

Recommendation

NSF establish a national postdoctoral fellowship program with three-year awards to candidates who at the time of their applications have not had their Ph.D. degree for more than one year.

2. Research career development awards. In view of the difficulty experienced by universities in finding "hard money" for the recruiting of young faculty members we are in danger of losing from basic science a generation of extraordinarily talented young investigators who in the absence of faculty positions might turn to other careers. To remedy this situation which may last 10-15 years (depending on the field and the institution) we propose the establishment of research career development awards to academic departments on behalf of specified individuals who have already demonstrated outstanding potential for careers in basic research. These awards for individuals who have three to five years of postdoctoral experience would entail NSF funds sufficient to pay full salary for a period of five years. The university in turn would be obligated to offer faculty positions, such as assistant professorships, and to consider these individuals on the regular academic ladder.

The award is not intended for the inexperienced and unproven investigator nor for those already established as independent scientists. Rather, it will be based on both the individual's credentials and the department's need and evident commitment to remedy the age imbalance of its faculty. The award would not only create faculty positions which would then become the obligation of the university to maintain but also it would assure that extraordinarily talented investigators remain engaged productively in basic research. Many details need to be elaborated such as reduced teaching responsibilities, possible renewal for one additional five-year term, and whether such renewal would be granted to those securing tenure.

Recommendation

NSF institute Research Career Development Awards to universities on behalf of specified young scientists who have already demonstrated their research potential but are not yet established as independent investigators.

3. Research scientist awards. Many mid-career scientists already on university faculties (as assistant or associate professors) desire to change their research activity to emerging fields and find it difficult, because of their university responsibilities, to make the transition. This program, which is in effect a three-year fellowship, would provide these talented individuals with an opportunity to do full-time research either in the same institution or at another laboratory. The award given directly to individuals of proven ability would constitute a leave of absence from normal university duties so that the investigators could devote full time to the new research. Such a program would facilitate mid-career changes for the most able, established young scientists who recognize the emergence of new research fields. We anticipate that these awards would not be renewable and that the departments would maintain their normal programs despite the absence of the individuals who would return at the conclusion of the three-year period. Criteria for judging the merit of the applications would have to be devised but they would certainly include the credentials of the individual, the nature of the proposed research, and the potential gain in basic research during and following the award period. In addition considerations would be given to the anticipated contribution to the upgrading of the department and the university.

Recommendation

NSF establish Research Scientist Awards to individuals who in their mid-career are already on university faculties and merit support for three years in order to change scientific fields or intensify their research activity.

4. National research professorships. Many of the discussions aimed at creating faculty opportunities for outstanding young scientists deal with attempts to provide faculty positions by encouraging the early retirement of faculty members who are no longer making significant contributions to science. It is explicitly recognized that those who are still creative and productive should not be included in these plans. Since it seems politically unrealistic to devote federal funds as inducements for the relatively unproductive scientists to retire, we propose as an alternative an award for those who are most distinguished for their contributions to science and from whom continued creative research is expected. Hence we propose the establishment of National Research Professorships to those who have long distinguished scientific careers,

and are recognized internationally as contributing importantly to exciting fields of science. The professorship would entail full salary awards paid by NSF. Nominations would be made by universities on behalf of individuals and departments and would require that the salary savings through the award would be devoted to the employment of young faculty members in the same department.

These National Research Professorships would be analogous to those of the American Cancer Society and would guarantee salaries for the active career of the individuals who would then be free of all university obligations so that full-time research can be assured. The establishment and awarding of these national professorships, as in the presentations of the National Medal of Science, would help to restore the public esteem of science while at the same time rewarding those who deserve it most and helping universities to generate faculty positions for younger investigators.

Recommendation

NSF establish National Research Professorships based on university nominations of internationally distinguished scientists whose contributions to basic research would be enhanced through full-time scientific activity.

5. Undergraduate summer research participation. In all discussions of improving science throughout the country the finding and encouraging young talented individuals emerges as one of the most important goals. Moreover, it is recognized that many of the exceptional students in small colleges and universities not renowned for scientific research are lost because of limited opportunities. In an effort to recruit these individuals to science we propose that NSF consider awards to institutions with proven records of training undergraduates who then go elsewhere for their doctoral work. These awards would be given directly to these schools for stipends to students who would go to outstanding research laboratories for summer experience. Such awards especially to those who have to work summers to meet their college expenses would permit them to receive summer income and at the same time prepare them for entry into scientific research upon their graduation. Such a plan would provide eager, bright assistants for those engaged in science in research-oriented universities. Many scientists now operating with grants from NSF are willing to employ undergraduate assistants during the summers but have difficulty in finding the most

talented apprentices. In our view the institutions who specialize in undergraduate education are in a better position to identify the talented undergraduates and arrangements could be devised whereby they could send these individuals to the institutions where the research is being conducted. Hence we propose direct grants to the undergraduate institutions for the recruiting of potential researchers and arranging their summer research experiences.

Recommendation

NSF devise a program of undergraduate research opportunity awards permitting outstanding students to participate in summer research.

6. Assistance to teaching institutions. Continuing to motivate young people with an extraordinary taste and talent for science is important for the long-range health of the country's science programs. Since many of our small teaching institutions, such as women's and minority colleges, have produced a disproportionate number of graduates who then attain their Ph.D. degrees at research universities, it is especially important that facilities for both research and teaching be improved at these teaching institutions. Programs for exchange of slightly outdated scientific instruments from research universities to teaching colleges would be very useful. This sharing of resources through special programs initiated by NSF could also include sponsoring short-term bilateral faculty exchanges between the two types of institutions. This type of program would provide both inspiration to young students through opportunities to take courses from visiting professors from research universities and permit the permanent faculty of the teaching institutions to become more effective teachers through their enhanced awareness of recent developments in science.

Recommendation

NSF consider special programs designed to enhance teaching and research at those undergraduate institutions with demonstrated records of effective education in science.

7. Research on research. In recent years there has been growing scholarly interest in the process of scientific research itself. This development has many names: the sociology of science, science policy studies, science indicators, etc. Those different names carry different nuances, but the central idea of studying science scientifically, of careful corporate introspective

investigation by the city of science, is both natural and important. In particular, the National Science Foundation is charged with the study of science policy, and thus has both the mission and the resources to lead in the scientific study of science. That leadership is represented in substantial part by a large number of studies and reports, of which the Science Indicator series form the flagships.

Much, although not all, of that activity bears on basic research in universities, either directly (e.g., dollar amounts of support for university basic research) or comparatively (e.g., comparisons of support of basic research in universities and in industries).

The Task Group believes that the scientific study of science is of great importance, not only as regards basic research in universities, but quite generally. However, the Group feels that too much of the scientific study of science has been superficial, and we recommend deeper and more intensive pursuit of this field. One way of characterizing our recommendation is that we would like to see NSF in-house and supported research on science policy reach the same levels of scientific quality that are found in the regular NSF disciplinary programs.

Of course there is excellent research on science policy, both in and out of the Foundation, and there are many reasons why it is difficult to do excellent work in so difficult and diffuse an enterprise as the scientific study of science. There is also rather poor work in the area, again both in and out of the Foundation. Our hope is that recommendations can be developed which will help to improve quality and thus help everyone to understand better the process of science, and the influences that help or hinder it.

Problems in the scientific study of science range from difficulties in clarifying what might at first be regarded as basic factual material to philosophical questions about the research orientation of a society and about the academic ethos.

As many writers have pointed out, the data in studies of science have been mostly in terms of input: money, people, equipment. Measuring output is indeed difficult, and there are serious problems with all measures thus far suggested or used: number of publications, citation counts, patent counts, innovation

frequencies. In this connection, we suggest prospective studies of the cumulative nature of research. Such studies would be distinguished from retrospective studies (e.g., TRACES) sponsored by NSF and other agencies, in which a current triumph of science or technology is traced back to its roots in basic research. A prospective study would, in contradistinction, begin with some cross-sectional sample of basic research results at an initial time, and then see how they motivated, fed into, or otherwise were related to future science and technology.

One fundamental reason for basic research in universities is its association with graduate instruction. Young scientists are thus socialized to research mores by osmosis, as it were, and faculty scientists are kept on their research toes by constant association with the brightest young minds. Indeed, at a university with good morale, resources, and momentum the line between research and graduate instruction in the sciences is impossible to draw. We all have our personal experiences and vicarious anecdotes about this system, but who has studied it systematically? How does it vary over fields of science? What happens at universities of the second and third ranks? How can the system adapt to shrinking budgets and employment opportunities?

The effects of egalitarian and social reform movements on universities, and the basic research done or not done there, call out for description and analysis. Is it possible to analyze rationally, for example, the tension between purely scientific criteria and criteria of geographical or social distribution in the allocation of funds? We do not agree with the extreme doctrinaire views on this question, but we know of no deep study of it.

Demographic predictions related to student populations, and to numbers of young scientists, need refinement and much study of error structure. More work is needed on the economics of R & D. It should go hand-in-hand with the suggested program of data clarification.

We realize that such studies have their difficulties and dangers, but we consider them of great potential importance.

Recommendation

NSF through a Task Group and in-house staff conduct more and better research on the process of scientific research.

8. University-industry cooperation in basic research. The Task Group is in full agreement with the Board's recently stated objective:

> "To develop a stronger national program in scientific research by increasing university-industry cooperation and mutual understanding through augmented support of cooperative research projects by NSF."

There is much to be gained through increased cooperation and guidelines should be developed that would encourage and facilitate collaborative basic research. Mobility of scientists between universities and industrial laboratories should be increased. At the same time safeguards should be devised so that the results of the basic research are published promptly in traditional ways. In view of the recent growth of profit-making companies composed largely of academic scientists special precautions should be considered regarding possible conflicts resulting from grants to these individuals at universities and the proprietary interests of the companies.

Recommendation

NSF continue studies of alternative arrangements for encouraging cooperative basic research between universities and industrial laboratories.

9. Retirement plans and incentives for early retirement. In view of the foregoing discussion about aging faculties and the limitations in faculty positions for younger scientists, it is imperative that accurate information be available regarding the problems in various scientific disciplines. NSF has already conducted studies which indicate that early retirement is not a way to create or effect quantitative changes of great magnitude in the availability of academic positions although it could have a significant qualitative impact in selected institutions and departments by permitting a small number of significant new appointments. The factors which will influence the employment opportunities for young scientists must be clarified. Since the balance between tenured and non-tenured positions varies markedly among institutions and scientific disciplines, simple solutions or the development of a single recommendation that would be all-encompassing would be neither reasonable nor effective. More information is needed.

Recommendation

NSF in collaboration with universities and professional societies continue investigation of existing retirement plans, retirement practices, incentive

plans to encourage early retirement, and the potential impact of recent legislation on the aging of faculties.

10. Equipment needs and utilization. Many of the advances in biology, physics and chemistry during the past three decades are based on the use of scientific instruments which permitted investigators to do experiments that were not possible earlier. The results of these studies have provoked questions which can be answered generally only with even more sophisticated instruments -- shorter or longer wavelength, detection at lower light levels, signal-to-noise enhancement, higher resolution, rapid computations, better temperature control, faster measurements, etc. Each scientific discipline has its own list of needed instruments. And they are more expensive than the earlier designs and more difficult to maintain. Hence sharing is becoming increasingly necessary. But to say that does not mean that arbitrarily a decision for sharing should be based on some specified cost like $10,000 or $20,000. How the instruments are used by scientists should determine whether sharing is feasible and justified. As stated by Coulter (20):

> "The instrument problem is not one problem but many, and coordinated solutions must be implemented with well-defined goals based on knowledge of the needs of the users and developers of instruments."

It seems likely that considerable gains could be achieved through exchange of instruments among research universities and teaching institutions. The former frequently discard working instruments when they need to replace them with more modern units. Yet it is very difficult to dispose of the old instruments in a way which would contribute to research and teaching elsewhere. Information about the needs of instruments and their availability would facilitate mutually beneficial exchanges.

Recommendation

NSF in conjunction with universities and professional societies continue investigations of equipment needs, maintenance and utilization for scientific research in different fields.

11. Facilities. Many excellent laboratories in this country were constructed with federal money that was contributed frequently to match privately raised or state contributed funds. For some years now such federal funds have

essentially been unavailable and, of course, it is increasingly rare to find universities using privately raised funds for new laboratory buildings. We have the impression that the need for new, safe laboratories is critical. Although we do not anticipate that funds to alleviate this need will become available in the near future, we think it appropriate that a study be conducted so that accurate information for different institutions and disciplines is available. With such data a scale of priorities might be developed which could be used in the political discussions which will doubtless occur before appropriations are made.

Recommendation

NSF in conjunction with universities conduct a study of existing laboratory facilities and their usage in order to prepare a realistic appraisal of needs for new laboratory construction.

12. Impact of federal regulations. Although we are aware that many of the goals of the federal regulations are worthwhile and that accountability of scientists and universities is necessary, we are troubled because many of the constraints are in fact impeding basic research. Moreover, the financial cost is great. It is perhaps unavoidable that so much conflict has arisen and certainly it was not unexpected. Misgivings about government controls were expressed by Compton (21) as early as 1934:

> "I confess to considerable doubt as to the wisdom of advocating support of scientific research .... If government financial support should carry with it government control of research programs or research workers, or if it should lead to political influence or lobbying for the distribution of funds, or if any consideration should dictate the administration of funds other than the inherent worth of a project or the capabilities of a scientist, or if the funds should fluctuate considerably in amount with the political fortunes of an administration or the varying ideas of Congress, then government support would probably do more harm than good ....."

Although much has been written on this subject (15,22,23) it seems clear that effort is needed to devise ways to reconcile the legitimate social demands for safety, fairness, and accountability with the requirements for maximum freedom in the conduct of scientific research.

Recommendation

NSF convene a Task Group to consider ways to ameliorate the deleterious impact of federal regulations on the conduct and cost of basic scientific research.

13. Uncoupling research and teaching. In earlier sections of this report we described the dim prospects for young scientists to find faculty positions in universities with few retiring faculty members and decreasing enrollments. From the evidence available we conclude that academic departments are likely to become smaller in the next 20 years if the size of faculties continues to be based on teaching responsibilities. This curtailment, if it occurs, will have serious consequences on the amount, and probably on the quality, of the science being conducted within universities. It seems logical, therefore, to consider some uncoupling of research and teaching so that decreases in the need for university teaching do not automatically cause a decrease in the amount of science being performed. This uncoupling should be partial if we are to preserve the advantages of the university for the pursuit of basic science. Perhaps, new research institutes on university campuses should be established. Perhaps, research professorships should be granted. Perhaps, there should be a formal allocation of teaching budget for partial salaries of faculty members and the remainder, for the research function, to be funded by granting agencies like NSF. Clearly patterns vary from institution to institution and from discipline to discipline. As in so many other problem areas we do not have sufficient information to offer a concrete proposal. But we think one is needed and it should be based on good evidence and thorough study. Therefore we urge the establishment of a Task Group to consider this problem.

Recommendation

NSF convene a Task Group to study existing policies within universities regarding allocation of teaching and research effort and salaries and consider alternative ways to uncouple research and teaching so that any decline in the number of teachers required in universities will not automatically lead to a reduction in scientific research.

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ALTERNATIVE SUPPORT MECHANISMS FOR UNIVERSITY RESEARCH

Projected sharp decreases in academic enrollment over the next fifteen or twenty years will undoubtedly result in severe difficulties for American colleges and universities. Resulting decreases in faculty hires and in financial resources, even at the best and most prestigious institutions, may make it difficult for our universities to continue as viable educational and research institutions.

The long-term health of the American scientific endeavor depends, at least in part, on the presence of vigorous and creative scientific activity in a university setting and on universities' ability to continue to train and to attract to their faculties the best and most talented young scientists. If one accepts this premise, then means must be found to maintain quality faculties, for an interim period of fifteen years or so, that exceed the number needed to fill educational and teaching needs.

Present support mechanisms may be inadequate to assure continued vitality and productivity during this period. Present mechanisms, which provide support largely for individual projects, individually proposed, are also sometimes criticized for being unduly cumbersome and demanding of effort in frequent proposal and report preparation and review.

The task group is asked to consider whether new and simpler types of support mechanisms can be devised which will maintain the vitality of research in universities without sacrificing quality. Among the possibilities that might be considered are:

- Career development awards to create new assistant professorships.
- Mid-career development fellowships to facilitate change in specialized fields of effort.
- Mid career research scientists positions, with or without diminished teaching duties.
- Senior research scientist positions, also with or without diminished teaching duties.
- Longer-term grants to established outstanding scientists.
- Grants to institutions or to departments or their subunits.